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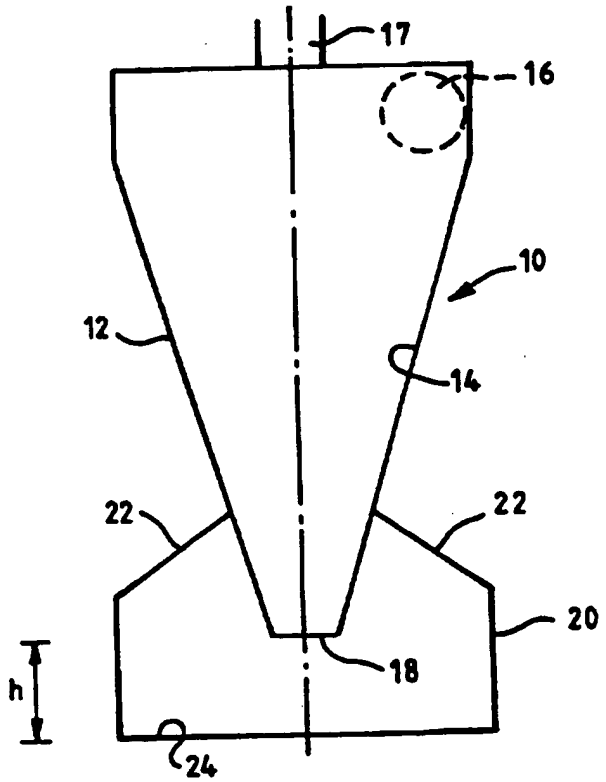
(54) Title: IMPROVED DUST SEPARATION APPARATUS

(57) Abstract

The invention provides apparatus (10) for separating dirt or dust from an airflow comprising a frustoconical cyclone (12) having a tangential air inlet (16) located at or adjacent the end of the cyclone (12) having the larger diameter and a cone opening (18) located at the end of the cyclone (12) having the smaller diameter. A collector (20) is arranged so as to surround the cone opening (18) and has a base surface (24) facing towards the cone opening (18). According to the invention, the distance between the cone opening (18) and the base surface (24) is either less than 8 mm or between 30 mm and 70 mm. This allows the apparatus (10) to be reduced in size without substantially affecting the separation efficiency.



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IMPROVED DUST SEPARATION APPARATUS

The invention relates to apparatus for separating dirt or dust particles from an airflow by cyclonic means. The invention relates particularly, but not exclusively, to cyclonic dust separation apparatus for use in a vacuum cleaner.

Cyclonic dust separation apparatus typically comprises a frusto-conical cyclone having a tangential air inlet at the end having the larger diameter and a cone opening leading to a dirt or dust collector at the end having the smaller diameter. The dust collector is generally cylindrical in shape and is considerably larger in diameter than the cone opening, normally having a diameter of at least three times that of the cone opening. In operation, an airflow carrying dirt and dust with it enters the cyclone via the air inlet and, by virtue of the tangential orientation of the air inlet, is set into a swirling motion over the interior surface of the cyclone. Most of the air of the airflow escapes from the cyclone by passing towards the longitudinal axis of the cyclone and exiting via an exit passage arranged substantially centrally of the end of the cyclone having the larger diameter. The remainder of the airflow spirals towards the cone opening at

increasing angular speeds carrying the dirt and dust with it and is ejected into the dust collector, whereupon the dirt and dust particles are flung towards the cylindrical wall of the collector. The dirt and dust particles then collect in the lower regions of the cylindrical wall, whilst the remainder of the airflow exits from the collector via the cone opening and the exit passage.

It is generally desirable for cyclonic dust separation apparatus to be relatively compact, particularly as regards the overall length of the apparatus, ie, the dimension parallel to the longitudinal axis of the cyclone. If the apparatus is used in a vacuum cleaner, compact dust separation apparatus reduced the overall dimensions of the complete cleaner and lowers the centre of gravity of the cleaner which, in turn, increases its stability. This is particularly advantageous in cylinder-type cleaners as well as upright-type vacuum cleaners.

It is an object of the present invention to provide dust separation apparatus which is relatively compact without any significant loss of dust separation efficiency.

According to the invention, there is provided apparatus as claimed in claim 1. Advantageous features are set out in the subsidiary claims.

It has previously been assumed that as large a

distance as possible between the base surface and the cone opening is desirable. This allows more volume in the collector for separated dirt and dust to accumulate before emptying is required and was also thought to reduce the likelihood of separated dirt and dust becoming re-entrained into the airflow. The distance between the base surface and the cone opening has therefore been limited merely by the desired overall dimensions of the machine of which the dust separation apparatus forms part. However, it has now been found that varying this distance can affect the separation efficiency of the apparatus. Maxima of separation efficiency for different sizes of cyclone and collector occur when the distance between the base surface and the cone opening lies in the range 30mm to 70mm. A particularly advantageous distance is 54mm. Surprisingly, a distance of less than 8mm, particularly around 4mm to 6mm, is highly efficient even though it was initially thought that such a small distance would adversely affect the airflow in the cyclone and collector. Reducing the distance between the base surface and the cone opening to 8mm or less therefore has an additionally advantageous effect on the overall dimensions of the apparatus without substantially detracting from the separation efficiency thereof. The centre of gravity of the separation apparatus is therefore lowered.

Embodiments of the invention will now be described with reference to the accompanying drawings, wherein:

Figure 1a is a sectional side view of a first embodiment of apparatus for separating dirt or dust from an airflow according to the invention;

Figure 1b is a sectional side view, corresponding to part of Figure 1a, of a second embodiment of the invention;

Figure 2 is a graph showing filtration efficiency test results for a 260mm cyclone with a flat-bottomed fine dust collector at varying distances from the cone opening;

Figure 3a is a sectional side view of a third embodiment of the invention;

Figures 3b and 3c are sectional side views, corresponding to part of Figure 3a, of fourth and fifth embodiments respectively of the invention;

Figure 4a is a sectional side view, corresponding to Figure 1b, of a sixth embodiment of the invention; and

Figure 4b is a sectional side view, corresponding generally to Figures 3b and 3c, of a seventh embodiment of the invention.

Figure 1a shows apparatus 10 for separating dirt or dust from an airflow consisting of a frustoconical cyclone 12 having an interior surface 14. An air inlet 16 is arranged at the end of the cyclone 12 having the larger diameter and the air inlet 16 communicates with

the cyclone 12 so as to introduce air tangentially into the cyclone 12.

At the end of the cyclone 12 having the smaller diameter, ie. remote from the air inlet 16, there is a cone opening 18. Surrounding the cone opening 18 and sealed against the outer walls of the cyclone 12 is a collector 20 for collecting dirt and dust separated from the airflow. The main body of the collector 20 is generally cylindrical in shape although inclined walls 22 extend between the generally cylindrical portion and the cyclone 12. The collector 20 has a base surface 24 facing towards the cone opening 18, ie. remote from the main body of the cyclone 12.

In use, an airflow consisting of a stream of air having dirt and dust particles entrained therein enters the cyclone 12 via the inlet 16. Because of the tangential entry arrangement, the dirt-laden airflow takes up a swirling motion inside the cyclone 12 and spirals over the interior surface 14 of the cyclone 12 towards the cone opening 18 at ever-increasing angular speeds, with clean air escaping from the cyclone 12 by moving inwardly towards the longitudinal axis and upwardly towards an exit port 17. As soon as the remainder of the airflow enters the collector 20 via the cone opening 18, the dirt and dust particles entrained within the airflow are flung towards the side walls of the collector 20. The airflow, which is substantially

free of dirt and dust particles, then exits the collector 20 via the cone opening 18 and leaves the cyclone 12 by means of the exit port 17 located substantially centrally of the end of the cyclone 12 having the larger diameter.

It has been found that, by varying the distance h between the base surface 24 and the cone opening 18, that the separation efficiency of the apparatus 10 can be improved. When the distance h is set at a value of between 30mm and 70mm, the separation efficiency increases. In particular, there is a peak in separation efficiency when the distance h is set at substantially 54mm.

It has also been found that the separation efficiency is particularly good if the distance h is reduced to less than 10mm. This is extremely surprising because it has previously been anticipated that such a small gap between the cone opening 18 and the base surface 24 would either restrict the airflow through the dirt or dust separation apparatus 10 or increase the likelihood of separated dirt or dust becoming re-entrained within the airflow. Tests have shown that this is not the case and that there is a particularly good separation efficiency when the distance h is between 4mm and 6mm. This arrangement is illustrated in Figure 1b.

Test results showing the variation in separation

efficiency for different distances between the base surface 24 and the cone opening 18 are shown in Figure 2. The tests were carried out on apparatus incorporating a 260mm cone and a flat-bottomed collector positioned at varying distances from the cone opening. The upper line shows the percentage of particles falling in the range 0.3-0.5μm present in the airflow after a standard test time, and the lower line shows the percentage of particles falling in the range 0.5-1.0μm present after the standard test time. Clear minima can be seen at distances of 4mm-6mm and 54mm.

Figures 3a, 3b and 3c illustrate alternative embodiments of the first aspect of the invention. The apparatus shown in Figure 3a corresponds closely to the apparatus shown in Figure 1a. The only difference between the apparatus shown in Figures 1a and 3a is the shape of the collector 20. In Figure 3a, the planar base surface 24 is replaced by a base surface 24' consisting of a frustoconical portion 24a surrounding a planar circular portion 24b. (The cylindrical portions of the collector 20 shown in Figure 1a have also been reduced in height.) The result is that the collector 20 shown in Figure 3a is substantially frustoconical in shape. This allows the entire apparatus 10 to be rotated about an axis running along any diameter of the central portion 24b so as to tilt the apparatus 10 with respect to a fixed surface parallel to that axis.

It had previously been expected that dirt and dust separated from the airflow on entry into the collector 20 via the cone opening 18 would travel down the inclined surfaces 24a of the collector 20 and accumulate in the region of the central portion 24b. It was thought that such an accumulation would result in the separated dirt and dust being re-entrained into the airflow. However, tests have shown that this re-entrainment does not occur.

In the embodiment shown in Figure 3a, the distance between the cone opening 18 and the central portion 24b of the base surface 24' is substantially 54mm. Furthermore, the angle of inclination α of the frusto-conical portion 24a with respect to the central portion 24b is substantially 50°. Also, the diameter of the central portion 24b is substantially identical to the diameter of the cone opening 18 and this is preferably substantially 25mm.

Various modifications and variations are possible within the context of this aspect of the invention: the distance between the cone opening 18 and the central portion 24b of the base surface 24' can be varied and, in particular, can be reduced to a distance of substantially 7mm. This spacing gives an increased separation efficiency. Such an arrangement is illustrated in Figure 3b.

A further alternative arrangement is illustrated in

Figure 3c which shows the collector 20 having a frustoconical portion 24a and a central circular portion 24b, but wherein the central circular portion 24b has a diameter k which is substantially larger than that of the cone opening 18. In the embodiment shown in Figure 3c, the diameter of the cone opening 18 is substantially 25mm, whereas the diameter of the circular central portion 24b is substantially 125mm.

Figures 4a and 4b illustrate an additional measure designed to reduce any possibility of dirt and dust collected in the collector 20 becoming re-entrained in the airflow circulating in the apparatus 10. This measure applies primarily in cases wherein the distance between the cone opening 18 and the base surface 24 is less than 8mm or wherein the base surface 24 is conical or frusto-conical in shape.

In order to reduce still further the possibility of dirt and dust located in the collector 20 from being re-entrained into the airflow, dirt and dust-retaining means in the form of a wall 30 are provided on the base surface 24. The wall 30 is upwardly extending with respect to the base surface 24 and is substantially annular in shape, although other plan shapes could be utilised. The diameter d of the annular wall 30 is substantially 70mm but this could be varied within the range 30mm to 100mm. The height w of the wall 30 is substantially 55mm from the junction between the wall 30

and the base surface 24 but could be varied within the range 20mm to 60mm.

The wall 30 has a tapering cross-section as shown in Figure 4a. The thickness of the wall 30 is greater at the end thereof adjacent the junction with the base surface 24 than at the distal end. The upper end of the wall 30 is radiused to form a smooth finish.

When the annular wall 30 is provided in conjunction with a frustoconical base surface 24 as shown in Figure 4b, the junction between the wall 30 and the base surface 24 is on the frustoconical portion 24a of the base surface 24. However, if the central portion 24b is sufficiently large in diameter, the junction between the wall 30 and the base surface 24 can occur in the central planar portion 24b.

In operation, air exiting the cyclone 12 via the cone opening 18 causes dirt and dust particles entrained therein to be flung against the outer walls of the collector 20. The annular wall 30 prevents the dirt and dust particles from travelling towards the central portion of the base surface 24 and thereby reduces the possibility of dirt and dust particles becoming re-entrained into the airflow.

It is envisaged that cyclonic dust separation apparatus as described above can be used to advantage in a number of different situations. The application to which it is envisaged that the present invention is most

likely to be applied is that of vacuum cleaning apparatus. Either of the aspects of the invention described above can be used in an upright or cylinder-type vacuum cleaner in order to lower the centre of gravity and/or reduce the size of the apparatus as a whole. It is also likely that the apparatus described above will be used in conjunction with further cyclonic dust separation apparatus specifically designed to remove larger dust and fluff particles in a so-called "low efficiency" cyclone. The apparatus described above will therefore be intended to remove only the finer particles of dirt and dust entrained in the airflow.

However, it is also envisaged that the invention described above may well be utilised in other situations, for example the removal or dirt and dust particles from internal combustion engine emissions. The principles described above are equally applicable to such situations and need not be used in combination with further cyclonic separation apparatus unless it is so desired.

CLAIMS

1. Apparatus for separating dirt or dust from an airflow comprising a frustoconical cyclone having a tangential air inlet located at or adjacent the end of the cyclone having the larger diameter and a cone opening located at the end of the cyclone having the smaller diameter, and a collector arranged so as to surround the cone opening and having a base surface facing towards the cone opening, wherein the distance between the cone opening and the base surface is either less than 8mm or between 30mm and 70mm.

2. Apparatus as claimed in claim 1, wherein the base surface is substantially planar.

3. Apparatus as claimed in claim 2, wherein the distance between the cone opening and the base surface is measured parallel to the longitudinal axis of the cyclone.

4. Apparatus as claimed in claim 3, wherein the distance between the cone opening and the base surface is between 4mm and 6mm.

5. Apparatus as claimed in claim 3, wherein the distance between the cone opening and the base surface

is between 45mm and 60mm.

6. Apparatus as claimed in claim 5, wherein the distance between the cone opening and the base surface is substantially 54mm.

7. Apparatus as claimed in any one of the preceding claims, wherein the base surface comprises dust-retaining means spaced from the centre thereof.

8. Apparatus as claimed in claim 7, wherein the base surface comprises dust-retaining means spaced from the centre thereof.

9. Apparatus as claimed in claim 8, wherein the dust-retaining means comprise an upwardly-extending annular wall.

10. Apparatus as claimed in claim 9, wherein the wall extends upwardly from the junction thereof with the base surface for between 10mm and 60mm.

11. Apparatus as claimed in claim 10, wherein the wall extends upwardly from the junction thereof with the base surface for substantially 55mm.

12. Apparatus as claimed in any one of claims 9 to 11,

wherein the diameter of the wall is between 30mm and 100mm.

13. Apparatus as claimed in claim 12, wherein the diameter of the wall is substantially 70mm.

14. Apparatus as claimed in any one of claims 9 to 13, wherein the thickness of the wall is greater at the end adjacent the junction with the base surface than at the end remote therefrom.

15. Apparatus as claimed in any one of claims 9 to 14, wherein the end of the wall remote from the junction with the base surface is radiused.

16. Apparatus as claimed in any one of the preceding claims, wherein at least a portion of the base surface is conical or frustoconical in shape.

17. Apparatus as claimed in claim 16, wherein the base surface comprises a frustoconical portion and a circular portion.

18. Apparatus as claimed in claim 17, wherein the diameter of the circular portion is substantially the same as that of the cone opening.

19. Apparatus as claimed in claim 17 or 18, wherein the diameter of the circular portion is between 20mm and 30mm.

20. Apparatus as claimed in claim 17, wherein the diameter of the circular portion is substantially 25mm.

21. Apparatus as claimed in claim 17, wherein the diameter of the circular portion is substantially greater than that of the cone opening.

22. Apparatus as claimed in claim 21, wherein the diameter of the circular portion is substantially 125mm.

23. Apparatus as claimed in any one of claims 17 to 22, wherein the circular portion is planar.

24. Apparatus as claimed in any one of claims 16 to 23, wherein the conical or frusto-conical portion of the base surface is inclined at an angle of between 30° and 50° to the longitudinal axis of the cyclone.

25. Apparatus as claimed in claim 24, wherein the conical or frusto-conical portion of the base surface is inclined at an angle of substantially 40° to the longitudinal axis of the cyclone.

26. Apparatus for separating dirt or dust from an airflow substantially as hereinbefore described with reference to any one of the embodiments shown in the accompanying drawings.

27. A vacuum cleaner incorporating apparatus according to any one of the preceding claims.

28. A vacuum cleaner as claimed in claim 27, further comprising further apparatus for separating dirt or dust from the airflow, the said further apparatus being positioned upstream of the said apparatus.

FIG.1a

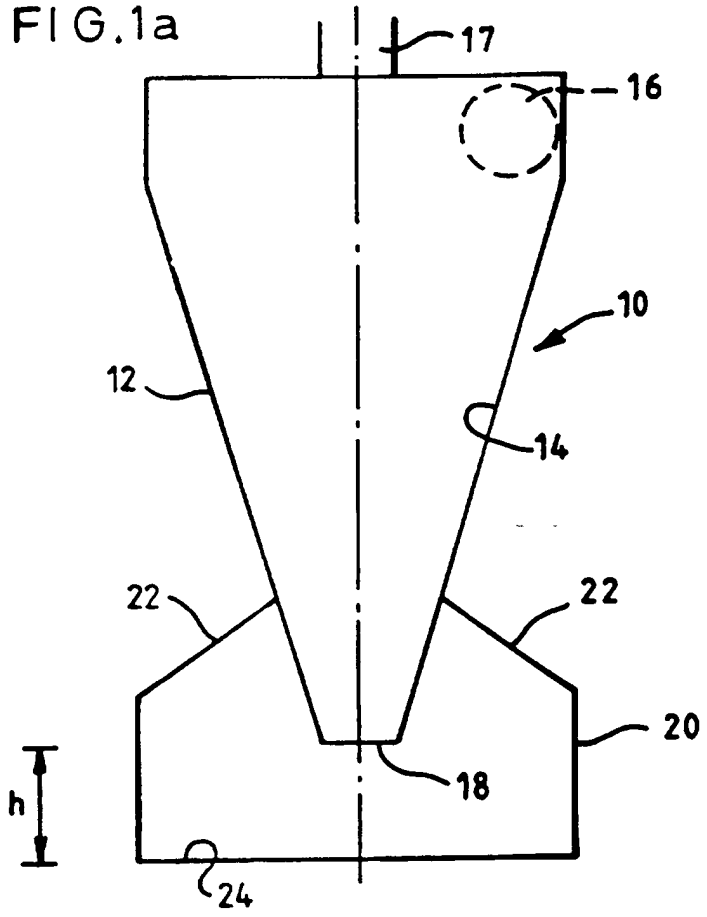


FIG.1b

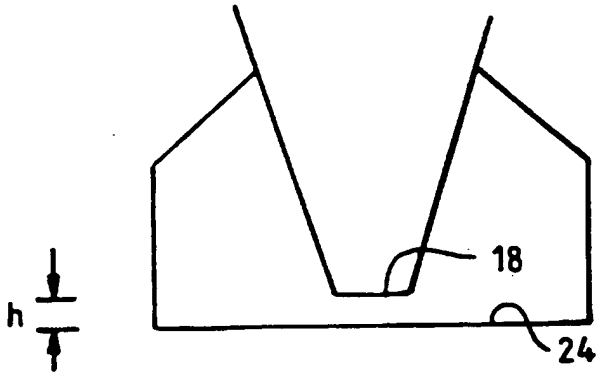
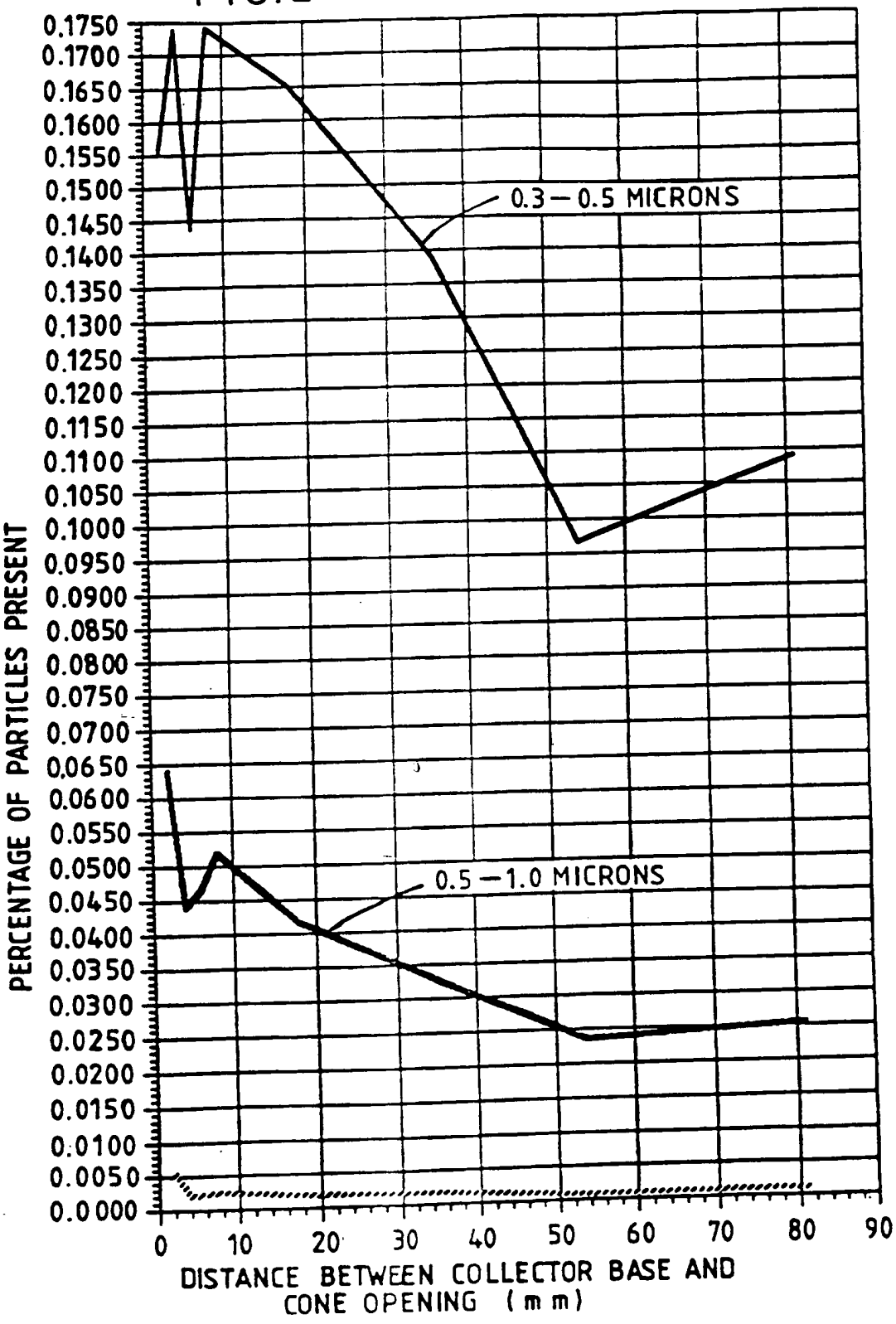


FIG. 2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0.0450
0.0400
0.0350
0.0300
0.0250
0.0200
0.0150
0.0100
0.0050
0.0000
PERCENTAGE OF PARTICLES PRESENT
0.3 — 0.5 MICRONS
0.5 — 1.0 MICRONS
0
10
20
30
40
50
60
70
80
90
DISTANCE BETWEEN COLLECTOR BASE AND CONE OPENING (mm)

FIG.3a

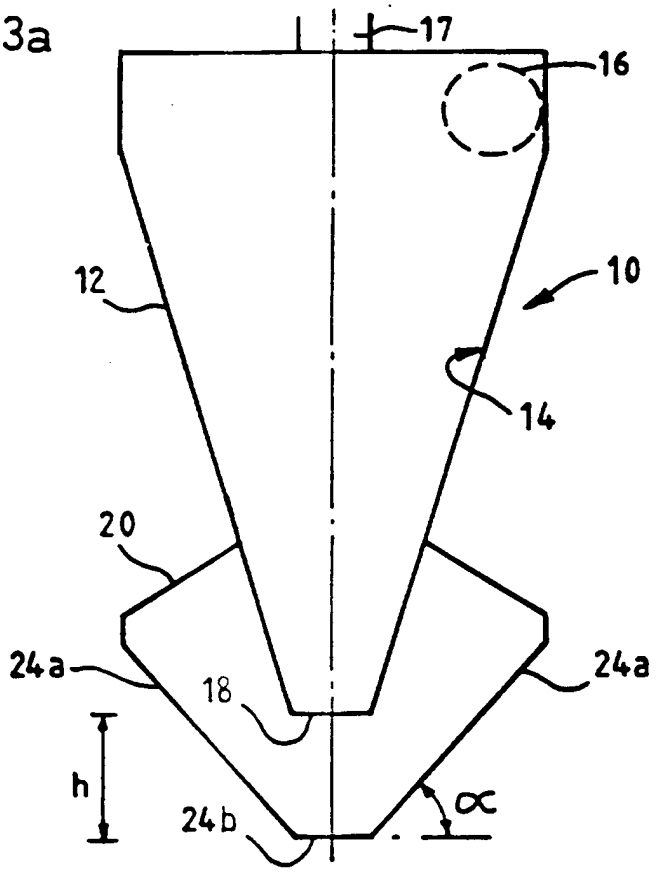

FIG.3b

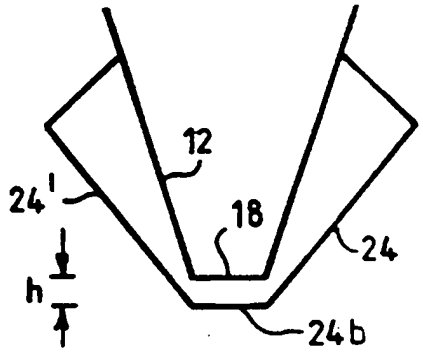

FIG.3c

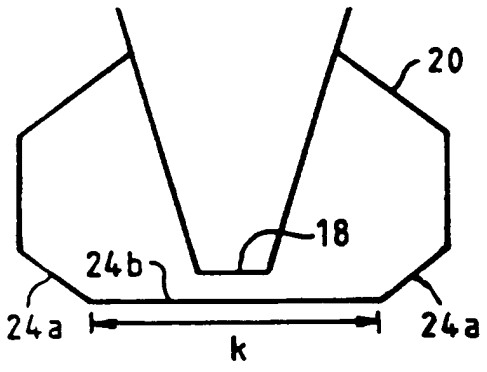

FIG.4a

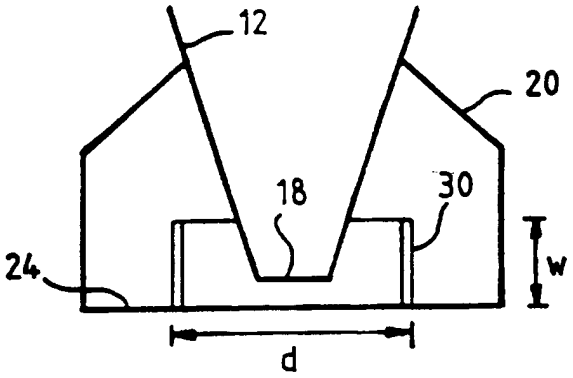

FIG.4b